H21A-04 0830h POSTER

Development of the 1997 Red River Flood: New Insight from Water Isotope Data

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During the spring of 1997 near record winter snowfall on the Red River basin combined with frozen soils and a rapid spring melt resulted in extensive flooding in North Dakota and Manitoba. Floodwaters were sampled from the Red River at four locations around Winnipeg and analysed for major and minor ions, and organic contaminants. Here we present new oxygen and hydrogen data for floodwaters sampled in the vicinity of Winnipeg prior, during and after the main peak of the 1997 flood and review the geochemical data in light of the information the isotopic composition of the water can provide about the source and history of the water. The depleted delta values, and relatively high d-excess measured in Red River samples from the ascending arm of the 1997 seasonal hydrograph support the interpretation from the very dilute geochemistry that the waters at the beginning of the flood originated as winter precipitation. As the main peak of the flood reached Winnipeg the isotopic composition of floodwaters remained within the range of winter precipitation while concentrations of some organochlorine and pesticides reached maxima. After the main peak of the hydrograph the specific conductivity of the floodwaters increased, with minor increases in dissolved major ions typical of groundwater, decreases in nitrate and nitrite, and increased potassium concentrations. During the falling limb of the snowmelt hydrograph the geochemical and isotopic composition of the floodwaters both indicate a greater proportion of groundwater. Combining geochemical indicators of surface water history with isotopic indicators of water source and history allows for qualitative interpretation of the evolution of floodwaters in the Red River. In this area of extremely flat topography and low permeability sediments the isotopic composition of floodwaters generated after spring melt are consistent with meltwater inputs dominating through the rising limb and peak of the flood hydrograph.

H21A-05 0830h POSTER

Isotopic monitoring (2H, 18O) of the St. Lawrence and Ottawa rivers between 1997 and 2003- Links with interannual climatic variability and hydrological processes in their catchment basins

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This study based on a water isotope (18O and 2H) monitoring of the St. Lawrence and Ottawa rivers (Canada) is a contribution to the international IAEA project: Isotopes tracing of hydrologic processes in large river basins [Gibson et al., 2002. EOS 83: 613 et p.]. Sampling of the St. Lawrence and Ottawa river waters started in 1997, on a biweekly to weekly basis. Monitoring stations are located at Montreal (i.e., at the outlet of the Great Lakes), Quebec City (the estuary of the St. Lawrence) and at the Carillon hydroelectric dam, near the outlet of a major tributary, the Ottawa River into the St. Lawrence itself. The goal of the study was to examine the seasonal and interannual variability of isotopic signatures of the St. Lawrence and Ottawa rivers, in relation notably with interannual climatic variations, and seasonal hydrologic processes in the watershed (summer evaporation, snowmelt, transit time of precipitation signals into runoff). Waters sampled at the three stations depict distinct isotopic compositions. At Montreal, relatively stable isotopic composition are observed with a mean weighted annual value of -54 $^{o}/_{oo}$ for 2H and -7.1 $^{o}/_{oo}$ for 18O. The Ottawa River water at Carillon also displays stable isotopic compositions but much lighter values (weighted mean annual values: -80 $^{o}/_{oo}$ for 2H and -10.8 $^{o}/_{oo}$ for 18O). Finally, isotopic compositions at Quebec City are intermediate between those of Montreal and Carillon, but show a much larger variability. They reflect mixing between the heavy isotope enriched Great Lakes water, the lighter water from the Ottawa River, and highly variable inputs from smaller tributaries (from the Laurentides and Appalachian mountains). The mean weighted isotopic compositions at Quebec City are -65 $^{o}/_{oo}$ and -8.6 $^{o}/_{oo}$, respectively for 2H and 18O). Evaporative enrichment, in particular during low water level episodes, seem to be more important in the Ottawa River catchment than in the Great Lakes basin, based on a comparison of isotopic clusters at Montreal and Carillon (figure 1). Relatively strongly correlated relationships are observed between isotopic compositions at the estuary of the St. Lawrence River (Quebec) and hydrologic variables such as water discharge. The best fit follows the equation : 2HQUEBEC = -1.9E-03 * QQUEBEC - 41.9, R2= 0.59. Such a relationship leads us to conclude that some properties of the regional hydrology can be relatively well described by stable isotope systematics. In contradiction, air temperatures are not well correlated with isotopic signatures partly because of lag times between them in relation to transit time of precipitation signal into runoff. A comparison of isotopic values in precipitation to those of runoff gives an estimate of the mean transfer time of water from the catchment to the river estuary. For summer heavy isotope enriched, but scarcer precipitation, a transit time of approximately 3 months is observed, whereas in winter, it can be as long as 4 to 5 months due to the residence time of winter precipitation in the snowcover. The assessment of the interannual variability of the St. Lawrence River isotopic system will require a better estimate of the isotopic inprint from small tributaries (that drain isotopically buffered ground waters, particularly in winter). Data are presently at processing stage.

H21A-06 0830h POSTER

14C and 13C Contents of Dissolved Organic Matter in the St. Lawrence Estuary and in a Hydroelectric Reservoir From the Boreal Forest (Quebec)

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In this study we examine the 14C and 13C contents of Dissolved Organic Matter (DOM) in the St. Lawrence River, at its outlet near Quebec City, and in a large hydroelectric reservoir, from the Canadian Boreal forest (Robert-Bourassa reservoir) as a mean to document the origin and residence time of DOM in such large catchments. Samples of DOM were collected biweekly at the Quebec City station from November 2001 until November 2002, as part of a geochemical monitoring program of the river, carried out since 1997. At the Robert-Bourassa reservoir, sampling operations took place from July 15 to July 26, 2001. All samples were filtered and acidified on site, and preserved in brown glass bottles at 4°C. Prior to their isotopic analysis, DOM samples were freeze-dried. 13C analyses were made at GEOTOP whereas 14C measurements were performed at the Lawrence Livermore National Laboratory, for samples coming from the St. Lawrence River, and at the *Laboratoire d'Hydrologie et de géochimie isotopique* of University Paris XI for samples originating from the Robert-Bourassa reservoir. Results are expressed respectively in $^{o}/_{oo}$ vs. V-PDB and in % of modern carbon (% MC; i.e. 13.56 dpm/g C in 1950, for d13C=-25 $^{o}/_{oo}$). D13C values averaging -26.3 ± 0.2 $^{o}/_{oo}$ in the St. Lawrence, and -27.1 ± 0.2 $^{o}/_{oo}$ at the Robert-Bourassa reservoir, indicate that DOC originates from terrestrial production, although a slight influence of aquatic DOC is seen in the St. Lawrence river during low water level episodes. In the river, DOC-14C activities range from 97.7 to 106.7 ± 0.5 %, with a mean value of 103.9 ± 0.5 %, whereas samples from Robert-Bourassa reservoir show a range of values between 108.5 and 110.5 ± 0.9 %, with a mean of 109.5 ± 0.9 %. In comparison, measurements made during the late 80's, in a small brook of Ontario, yielded 14C-DOM activities ranging from 113 to 118 % MC (Schiff et al., 1990). Meanwhile, 14C-activity of atmospheric CO2 has decreased of approximately the same proportion. We conclude that soil-derived DOC represents the production of immediately preceding years, notably in the Boreal Forest reservoir, but that contribution of longer residence time DOC from the Great Lakes likely accounts for the slightly lower 14C-DOC values found in the St. Lawrence River. In conclusion, 14C and 13C contents indicate an overall short DOM residence time, thus that the primary production at its origin, and its degradation and transport in the drainage network are fast processes. Reference: Schiff, S. L., R. Aravena, S. E. Trumbore et P. J. Dillon. 1990. Dissolved organic carbon cycling in forested watersheds : a carbon isotope approach. Water Resources Research, 26, no 12, 2949-2957.

H21A-07 0830h POSTER

Assessing Sources and Ages of Organic Matter Supporting River and Estuarine Bacterial Production: A multiple Isotope (Δ^{14}C , δ^{13}C, and δ^{15}N) Approach

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We used radiocarbon (Δ^{14}C) and stable isotopic (δ^{13}C, δ^{15}N) signatures of bacterial nucleic acids to estimate the sources and ages of organic matter (OM) assimilated by bacteria in the Hudson River and York River estuary. Dual isotope plots of Δ^{14}C and δ^{13}C coupled with a three-source mixing model resolved the major OM sources supporting bacterial biomass production (BBP). However, overlap in the stable isotopic (δ^{13}C, δ^{15}N) values of some of the potential source end-members (i.e., terrestrial, freshwater phytoplankton, marsh-derived) prohibited unequivocal source assignments for certain samples. In freshwater regions of the York, terrigenous material of relatively recent origin (i.e., decadal in age) accounted for the majority of OM assimilated by bacteria (49-83%). Marsh and freshwater planktonic material comprised the other major source of OM, with 8-33% and 6-25% assimilated, respectively. In the mesohaline York, BBP was supported primarily by estuarine phytoplankton-derived OM in the spring and summer (53-87%) and by marsh-derived OM in the fall (as much as 83%). Isotopic signatures from higher salinity regions of the York suggested that BBP there was fueled predominantly by either estuarine phytoplankton-derived OM (July and November) or by material advected in from the Chesapeake Bay proper (October). In contrast to the York, BBP in the Hudson River estuary was subsidized by a greater portion (up to 25%) of old (24,000 BP) allochthonous OM, presumably derived from soils. These findings collectively suggest that bacterial metabolism and degradation in rivers and estuaries may profoundly alter the mean composition and age of OM during transport within these systems and prior to its export to the coastal ocean.

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H21B CC: 220 C-E Tuesday 0830h

Environmental Vadose Zone Hydrology Posters

Presiding: **M H Young,** Desert Research Institute**; T Harter,** University of California, Davis

H21B-01 0830h POSTER

Lattice Boltzmann Modeling of Gaseous Diffusion in Unsaturated Porous Media under Variable Gravity Conditions

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Liquid distribution in unsaturated porous media under different gravitational forces and resulting gaseous diffusion coefficients were investigated to enhance understanding of plant growth conditions in microgravity.

Different fluid behavior in plant growth media under microgravity conditions as compared to earth presents a challenge to plant growth in long duration space exploration missions. Our primary objective was to provide qualitative description and quantitative measures of the role of reduced gravity on hydraulic and gaseous transport properties in simulated porous media. We implemented a multi-phase lattice Boltzmann code for equilibrium distribution of liquid in an idealized two-dimensional porous medium under microgravity and "normal" gravity conditions. The information was then used to provide boundary conditions for simulation of gaseous diffusion through the equilibrium domains (considering diffusion through liquid phase negligibly small). The models were tested by comparison with several analytical solutions to the diffusion equation, with excellent results. The relative diffusion coefficient for both series of simulations (with and without gravity) as functions of air-filled porosity was in good agreement with established models of Millington-Quirk. Liquid distribution under earth's gravity featured increased water content at the lower part of the medium relative to the distribution in reduced gravity, which resulted in decreased gas diffusion through a vertically oriented column of a porous medium. Simulation results for larger domains under various orientations will be presented.

H21B-02 0830h POSTER

Behavior of Adaptive Time Stepping in a Numerical Richards Equation Model

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The performance of various adaptive time stepping strategies together with improved initial estimates in the iterative solution of the nonlinear Richards equation governing flow in unsaturated porous media is evaluated. The so-called heuristic technique uses, a posteriori, the convergence behavior of the iterative scheme to estimate the next time step size (eg, increase the step size if convergence was fast, decrease it if convergence was slow). A priori techniques adapt the step size on the basis of an approximation of the local time truncation error obtained for instance from finite difference estimates of the first and second order time derivatives. The local error estimate is used to predict the largest step size that satisfies a preset error tolerance. Mass balance criteria can also be used to guide step size selection. Several sample problems are used to assess these various schemes. The influence of chord slope approximations to the derivatives of the hydraulic functions in the presence of steep gradients is also included in the assessment. It is found for example that higher order initial solution estimates improve the convergence of the Picard linearization scheme when using the a posteriori technique. When simulating strong nonlinearities, the a priori technique diminishes computational performance; the a posteriori technique seems to be more appropriate to guide the simulation under such circumstances.

H21B-03 0830h POSTER

Geologically-Based Modeling of Unsaturated Flow Through Heterogeneous Alluvial Sediments, Lawrence Livermore National Laboratory, California

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Groundwater flow and transport modelers have recently realized the value of incorporating geologically realistic heterogeneities into their models. This study applies the same philosophy to the vadose zone at the Eastern Landing Mat (ELM) site at Lawrence Livermore National Laboratory, California. A series of pneumatic tests were conducted at the ELM site to evaluate approaches to remove high VOC concentrations. The pneumatic data measured during the tests appear to show a heterogeneous distribution of pressure drawdown with distance. Our research examines the role of vadose zone heterogeneities in the development of the measured responses. The pressure drawdown data will be evaluated through numerical simulations of the pneumatic tests. Core and geophysical well log data, along with conceptual facies models, provide (1) a stratigraphic framework for evaluating the site, (2) parameters used to develop Markov chain models of spatial variability, and (3) conditioning data for transition probability geostatistics. Through geostatistics, multiple realizations of facies distributions were developed for the ELM site. These realizations will be used to simulate 3-dimensional vadose zone flow based on the Non-isothermal Unsaturated Flow and Transport (NUFT) code, calibrated to the pneumatic data. We expect to be able to use these methods to locate the high permeability zones that act as short-cut pathways of air flow and mass movement. Such information could then be used to design an optimal remediation strategy such as an efficient soil vapor extraction system.

H21B-04 0830h POSTER

Prediction of two-phase capillary pressure-saturation relationships in fractional wettability systems

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In order to simulate the migration of dense non-aqueous phase liquids (DNAPLs) multiphase flow simulators typically require the specification of fluid and porous medium specific constitutive relationships, including capillary pressure/saturation relationships that depend on wettability. Capillary pressure/saturation data, however, are often difficult and time consuming to measure, particularly for non-water-wetting soils. In this study, a series of capillary pressure/saturation experiments was conducted in uniform and fractional wettability systems. Intermediate and organic-wet sands were created by treating quartz sands with Rhodorsil Siliconate 51T and octadecyltrichlorosilane solutions, respectively. Two-phase (water-tetrachloroethene) capillary pressure/saturation data were quantified using two measurement systems, a pressure cell apparatus and a rapid automated pressure cell apparatus. Analyses of these data found that existing models are unable to predict capillary pressure/saturation curves for the broad range of wettability conditions likely in the contaminated subsurface. A new capillary pressure/saturation model, based upon the Leverett and Cassie equations, was developed to predict drainage and imbibition retention functions for a range of wetting conditions. This Leverett-Cassie equation was validated with data from a number of water/intermediate and water/organic fractional wettability DNAPL/water experiments conducted in this study, as well as data from two published studies. The Leverett-Cassie equation yielded good predictions of observed primary drainage and imbibition capillary pressure/saturation behavior. This model is easy to implement, with relatively few input parameters, and is applicable to a broad range of wetting conditions.

H21B-05 0830h POSTER

Predicting Non-ideal Infiltration Behavior in Soils

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A common problem experienced by those who estimate infiltration of precipitation into unsaturated porous media is the difficulty in accurately reproducing data collected from field infiltration experiments for all types of soils. A recent comparative evaluation of fourteen popular, matrix-based infiltration models, some physically based, some semi-empirical and some empirical, was conducted on 243 sets of infiltration data collected from field and laboratory tests on 23 different types of soil. For 7 of these soils, none of the 14 evaluated infiltration models were able to reproduce the observed infiltration. Infiltration through several other soils was only satisfactorily reproduced by a small handful of models. Further investigation reveals the problem soils all to be coarse-grained sands. It can be shown that in soils where gravitational forces can overcome restraining capillary forces, such as coarse-grained soils, instabilities in infiltration through the vadose zone will result. This type of behavior is not accounted for in matrix-based infiltration models and thus they are unlikely to accurately simulate infiltration in such soils. The ability to identify whether a particular soil might not behave according to matrix-based infiltration assumptions is therefore very desirable. Current research into identifying measurable soil parameters that can be used as predictors of the applicability of matrix-based infiltration models for various soils is being conducted. A parameter that has shown some ability to predict this behavior is the Bond number, which is the ratio of gravitational forces to capillary forces. Results of this research to date will be presented.

H21B-06 0830h POSTER

A comparison of point source infiltration behavior in soil systems with and without surfactant

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The infiltration of water is the first step in the downward propagation of precipitation and dissolved contaminants through the subsurface. The advance of the infiltrating fluid within the vadose zone is driven by capillarity and gravitational forces. Natural organic matter occurring near the soil surface, as well as anthropogenic organic contaminants, can reduce the surface tension of the infiltrating water, thus affecting the capillary component of hydraulic head. Two-dimensional numerical modeling was performed with HYDRUS-2D to assess the effect of surface tension reduction on shallow infiltration from a point source. Comparison of infiltration behavior in a surfactant-free system to the behavior in a system in which the infiltrating fluid contained a surfactant revealed significant differences between the systems. For given soil water conditions, infiltration of lower surface tension water decreases the contribution of capillary forces relative to gravity. That is reflected in the shape of the wetted-region with lower surface tension systems generating narrower/deeper wetted-regions. The shape of the wetted-region relative to that generated using simple scaling relations for the hydraulic functions was also evaluated.

H21B-07 0830h POSTER

Factors Affecting Moisture Exchange in the Organic Layer of the Forest Floor

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Virtually all of the mineral soil in the Canadian boreal forest is covered by a layer of decomposing organic matter known as duff. Due to its highly porous nature, only a small portion of incoming precipitation is absorbed by the duff layer, even when it is not completely saturated. The duff layer fosters high percolation rates to the mineral soil below and dries rather quickly; thus, it has a relatively low moisture content. This level of moisture content is not conducive to either seed germination or seedling survival. Duff consumption during forest fires provides areas of exposed mineral soil that are suitable for seed germination. Tree

regrowth is much more likely to occur in areas where the mineral soil has been exposed. The location and amount of duff consumed during a fire is a function of several factors including duff density, depth and moisture content. Factors affecting duff moisture content include its physical characteristics, overlying canopy type, hillslope position, soil type and climate. In this study, an investigation is made into the relative significance of capillary suction and other processes influencing the moisture exchange between duff and mineral soil. These processes are analysed in a controlled laboratory experiment using duff collected from different types of canopies. The duff samples, extracted from the boreal forest in central Saskatchewan, were collected from canopies of black spruce, jack pine and trembling aspen. Comparisons are made between the overlying canopy types, as well as between samples from similar canopies at different locations. Physical properties of the duff, such as the porosity and hydraulic conductivity, are analysed in combination with soil-duff interactions. The influence between mineral soil and duff moisture is determined through the use of a soil column that allows for both variable soil moisture and precipitation inputs. Results from this investigation give insight into the relationship between duff and soil moisture.

H21B-08 0830h POSTER

Impacts of Land use and Cover Change on Soil Hydraulic Properties, Rondonia, Brazil

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There is a great deal of concern in the scientific community and the popular media about the global impacts of tropical rainforest deforestation. Soil quality does not receive that same media coverage but is greatly affected by deforestation and is a major concern in the tropics, especially in areas undergoing rapid land use and land cover change. Deforestation can lead to changes in the hydrologic regime, loss of topsoil, increased sediment and nutrient loads in waterways, and decreased soil fertility. These impacts are often related to a soil's infiltration capacity and hydraulic conductivity (Ksat). Our research site, Rancho Grande, Rondonia, Brazil, lies in the heart of the most rapid tropical rainforest deforestation in the world. Two watersheds of similar size, comparable topographic relief, and same soil type, were tested for differences in hydraulic conductivity. The two watersheds are differentiated by land use and land cover; one in a primary forest and the other in an actively grazed pasture. We measured infiltration capacity at 13 locations in the primary forest watershed and at 24 locations in the actively grazed pasture. Approximately 150 measurements of Ksat were made at regular depth intervals in both watersheds. Our research focuses on assessing the impact of land use and land cover change (primary rainforest to pasture/grazing) on soil infiltration capacity and subsurface saturated hydraulic conductivity. Statistically significant differences in infiltration capacity and hydraulic conductivity were detected between the pasture and forest sites at depths of 0, 12.5, and 20 cm. Differences between the two sites at depths of 50 and 90cm were not significant. These results demonstrate that the affect of land cover and land use change on soil hydraulic conductivity was confined to shallower depths in the soil profile. Coupled with ongoing watershed runoff studies at Rancho Grande, this research will help clarify how land cover change affects soil hydraulic properties and resulting runoff dynamics.

H21B-09 0830h POSTER

Soil Moisture Patterns in a Small Forested Catchment: Hydropedological Investigations

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Much effort by non-pedologists is hampered because soil distribution and processes are not well understood that site selection for sampling or monitoring and the design of modeling do not represent actual distribution and processes. To connect pedon and landscape phenomena, one of the keys lies in the distribution of various soils over the landscape (i.e., soil patterns). The fabric of soil over the landscape helps optimal sampling design as well as appropriate modeling of landscape hydrology. This strategy, reflected in hydropedological approaches, is important in understanding spatio-temporal dynamics of soil moisture over the landscape. We investigated surface and subsurface soil moisture patterns in a small forested catchment in central Pennsylvania through mapping and monitoring, and then explored the underlying mechanisms for such patterns. Soil distribution and topographic metrics were emphasized in correlating with the observed soil moisture patterns. The preliminary analysis indicated that the surface soil moisture acted as a signature of the hydrologic dynamics of this catchment, while the subsurface soil moisture was more spatio-temporally stable over the monitoring period.

H21B-10 0830h POSTER

Phosphorus Transport at the Field Scale by Monitoring Groundwater and Interflow Discharge in Hydrologically Sensitive Areas in Agricultural Fields

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Quantification of nonpoint source of phosphorus losses through agricultural land is important because hydrologically active areas can significantly affect water quality. In this study we examined phosphorus concentration and phosphorus losses from hydrologically sensitive areas and upland areas located in valley soils in the Cannosville basin in Catskill Mountains. Phosphorus concentrations as low as 0.01 - 0.02 mg/L in water increase the algael bloom in lakes and reservoirs and the Cannosville basin is currently restricted to 0.02mg/L. We measured grab surface water samples taken along the creeks to study the phosphorus concentration in the sub-superficial runoff that drains water from the surrounding hills. Also we installed two different transects of piezometers, one line upstream and one line downstream, to study the role of the groundwater component and its effect in the hydrologically sensitive areas. We generally found low phosphorus concentration in the grab surface water samples and the groundwater samples taken in the piezometers. Sampling during the highest creek flow has resulted in the highest concentrations, generally near 0.05 mg/L of dissolved reactive phosphorus. These concentrations were slightly higher than the concentrations in most of the wells, which were around 0.03 mg/L. Sampling is ongoing to determine the effects snow melt contributions. Results will be presented to show the seasonal effects of phosphorus in the hydrologically sensitive areas.

H21B-11 0830h POSTER

Strontium Isotopes in Pore Water as an Indicator of Water Flow at the Proposed High-Level Radioactive Waste Repository, Yucca Mountain, Nevada

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The proposed high-level radioactive waste repository at Yucca Mountain, Nevada, would be constructed in the high-silica rhyolite (Tptp) member of the Miocene-age Topopah Spring Tuff, a mostly welded ash-flow tuff in the ~500-m-thick unsaturated zone. Strontium isotope compositions have been measured in pore water centrifuged from preserved core samples and in leachates of pore-water salts from dried core samples. Strontium isotope ratios ($^{87}Sr/^{86}Sr$) vary systematically with depth in the surface-based boreholes. Ratios in pore water near the surface (0.7114 to 0.7124) reflect the range of ratios in soil carbonate (0.7112 to 0.7125) collected near the boreholes, but ratios in the Tptp (0.7122 to 0.7127) at depths of 150 to 370 m have a narrower range and are more radiogenic due to interaction with the volcanic rocks (primarily non-welded tuffs) above the Tptp. An advection-reaction model relates the rate of strontium dissolution from the rocks with flow velocity. The model results agree with the low transport velocity (~2 cm per year) calculated from carbon-14 data by I.C. Yang (2002, App. Geochem., v. 17, no. 6, p. 807-817). Strontium isotope ratios in pore water from Tptp samples from horizontal boreholes collared in tunnels at the proposed repository horizon have a similar range (0.7121 to 0.7127), also indicating a low transport velocity. Strontium isotope compositions of pore water below the proposed repository in core samples from boreholes drilled vertically downward from tunnel floors are more varied, ranging from 0.7112 to 0.7127. The lower ratios (<0.7121) indicate that some of the pore water in these boreholes was replaced by tunnel construction water, which had an $^{87}Sr/^{86}Sr$ of 0.7115. Ratios lower than 0.7115 likely reflect interaction of construction water with concrete in the tunnel inverts, which had an $^{87}Sr/^{86}Sr$ <0.709. These low Sr ratios indicate penetration of construction water to depths of ~20 m below the tunnels within three years after construction, a transport velocity of ~7 m per year. These studies show that construction activities locally may alter the characteristics of the ambient hydrologic system at Yucca Mountain. This work was performed in cooperation with the U.S. Department of Energy.

H21B-12 0830h POSTER

Distribution of Colloid Particles onto Interfaces in Unsaturated Porous Media

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Very few direct observations have been made of colloid transport in unsaturated porous media. Studies have typically been limited to the evaluation of breakthrough curves from column experiments. Because breakthrough curves give only an integrated response, differing and sometimes conflicting colloid retention mechanisms have been proposed. To assess the validity of proposed mechanisms, we carried out pore scale visualization technique using combination of video microscopy, real time digital imaging and still images. Transport and retention of 5 mm hydrophilic (carboxylated latex) and hydrophobic (polystyrene latex) colloid microspheres in an unsaturated packed porous media (quartz sand) were investigated. We were able to derive mechanisms of hydrophilic colloids retained at the air-water-solid (AWS) interface instead of at the air-water interface in unsaturated media. Colloids were retained at the AWS interface at a location where the film thickness was approximately equal to the colloid size; the thin film of water near the meniscus provides an additional force for the colloid to stay in the interface. We also show that a colloid attaches to a colloid already present at the AWS interface. Mechanisms for hydrophobic colloids differed slightly. Images showed that these colloids were retained not only at AWS interface but also at solid-water and air-water interfaces, due to the hydrophobic characteristic of the colloids impelling them to avoid water. From the observations we were able to document that the sand grain surface irregularities was one of the major factor in the retention of colloids in unsaturated packed porous media

URL: http://www.bee.cornell.edu/swlab/colloids/videos

H21B-13 0830h POSTER

Spatial Variations of Residual NAPL Zone Concentration in Subsurface

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Improved models of residual nonaqueous phase liquid (NAPL) dissolution in the subsurface are presented to incorporate spatial variation of the residual zone source concentration. The new models are proposed based on the previously developed simple screening models under the assumption of proportionality between the residual NAPL source zone concentration and the remaining residual NAPL mass. The objective of the models is to predict the solute concentration in the zone of the residual NAPL as a result of dissolution. The proposed residual NAPL dissolution models enable the pseudo-equilibrium formulation to be used and therefore the numerical simulations for field application problems can be simplified compared to the non-equilibrium counterpart. With proper choice of empirical parameters, the proposed simple screening models can work as well as more complex dissolution rate correlation models. The models are especially useful for situations of small residual NAPL saturation, which

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are typical for many field applications. The previous screening models lumped the entire NAPL source zone together without considering the spatial distribution of NAPL source zone concentrations. The new models will incorporate the fact that the NAPL mass in the upstream will dissolve first. It will create a dissolution zone and this zone will travel downstream at certain velocity. Based on this consideration, the NAPL zone concentration is dependent on not only the time but also the distance into the NAPL zone.

H21B-14 0830h POSTER

A Three-Dimensional Water Flow and Solute Transport Model in the Context of two Contrasting Boundary Conditions in Unsaturated Zone

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ABSTRACT A Three-Dimensional numerical model based on the Richards Equation and the Explicit Characteristic Galerkin Method for water flow and solute transport respectively was tested with potential seepage face and impermeable boundaries in the unsaturated zone. The test problem, envisaged as a representative section of a paddy field under irrigation for which the model will be used to predict water and solute movement during the growth period of rice and beyond, received solute with infiltrating water from the ground surface. The infiltration rate and solute concentration were kept constant as the soil moisture increased until the flow region became fully saturated, and then infiltrated water was allowed to recede through natural drainage. Usually, in order to save computation time, especially for three-dimensional cases, seepage face boundaries are undesirable while impermeable ones are sometimes hypothetical. The results indicate almost identical water flow and solute movement pattern prevailing during infiltration for both boundary conditions, but during drainage only seepage face boundaries seem to represent well the physical reality of ground water flow. Solute movement is significant during infiltration phase of simulation and confined to the saturated part. During drainage the movement is to the lesser extent and appears mainly near the boundaries in the unsaturated part. Generally, the model gives the expected trend for water flow and solute transport.

H21C CC: 220 C-E Tuesday 0830h

Tracers in Hydrology II Posters *(joint with B)*

Presiding: **B L McGlynn,** Montana State University**; M Weiler,** University of British Columbia

H21C-01 0830h POSTER

Hydrological implications of 234U/238U disequilibria observed along pressure dissolution discontinuities in deep Mesozoic limestone formations of the Eastern Paris basin

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Borehole core samples from the deep, low-permeability Mesozoic formations surrounding the target argilite layer of the Meuse/Haute-Marne experimental site of the French agency for nuclear waste management -ANDRA- were analyzed for their uranium isotopic abundance. This study attempts to decipher the history and the processes governing the mobility of uranium in such geological settings by means of precise measurements of the (234U/238U) activity ratio. Limestone zones characterized by pressure dissolution structures (stylolites or dissolution seams) display systematic (234U/238U) disequilibria: i) the material within the seams shows a deficit of 234U over 238U ((234U/238U) down to 0.80) and ii) the surrounding carbonate matrix is characterized by an activity ratio greater than unity (up to 1.05). These results highlight a discret, centimetric-scale uranium remobilization in the limestone formations along these subhorizontal seams during the last 1-2 Ma and, consequently, active water/rock interaction processes since fractionation of 234U vs 238U necessary involves exchanges at the water/rock interface and migration via interstitial fluid. The nature and the modalities of the driving processes responsible for these disequilibria are not unequivocal, but different scenarios can be put forward to explain the U-remobilization observed: 1) late epidiagenetic processes associated to the presence of pressure dissolution structures, or 2) preferential fluid circulation along the stylolitic pathway. The major consequences in terms of the conceptual modeling of the hydrology behavior of the formations and, obviously, on the site performance assessment, are discussed.

H21C-02 0830h POSTER

The Effect of Transient Flow on Contaminant Dispersion in Porous Media

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Our ability to predict solute transport in groundwater is limited by our imperfect understanding of the physical processes governing the spreading of underground contaminant plumes beneath the surface. Inaccurate prediction of solute migration can in turn result in unreliable risk analyses, or higher costs for groundwater decontamination. It is generally accepted that spatial variations in the hydraulic conductivity of porous materials largely contributes to the spreading of solutes dissolved in groundwater. Unsteady hydraulic gradients can also enhance this dispersion by imposing an additional source of variability on the flow field. Most field and numerical studies assume steady state groundwater flow, despite compelling field evidence suggesting that flow transience may be ubiquitous. This study characterizes the effects of transient groundwater flow on contaminant migration in both homogeneous and heterogeneous porous media. The macroscopic dispersion of miscible solutes subjected to unsteady flow fields is assessed quantitatively through a series of laboratory experiments and numerical simulations. An innovative laboratory model is introduced, which consists of a two-dimensional flow cell and coupled hydraulic control system that allow the construction of spatially homogeneous or heterogeneous porous media of prescribed statistical properties, and to impose deterministic flow transients on the system. A monitoring procedure combining image processing with spatial moment analysis is used to characterize with great spatial and temporal resolution the evolution of contaminant plumes, as measured from sequences of digital images acquired during the course of laboratory experiments. Results suggest that the influence of flow transience on solute dispersion compares well with results reported in the literature, based on theoretical or numerical investigations. Changes in the mean flow direction significantly increase transverse dispersion in proportion to the rotation angle; conversely, longitudinal dispersivity decreases in response to variations in the flow direction, but to a lesser extent. Reversing hydraulic gradients can cause a reduction in the plume extents, or plume "shrinking". Although both the spatial and temporal variability enhance solute spreading, heterogeneity of the porous medium can mask the temporal variations in the flow field. The increased complexity introduced by the spatial and temporal variability can lead to inconsistencies between experimental and numerical models.

H21C-03 0830h POSTER

Determination of groundwater recharge rate using multiple tracers

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Ground water rate is a critical hydrological parameter for understanding groundwater contamination and for groundwater assessment and management. The objective of this study is to determine groundwater recharge rate and transport mechanisms in the unsaturated zone using long-term natural and applied tracers in a semiarid region, Saskatchewan, Canada. Tritium, applied Cl, natural NO3, and SO4 in soil profile were analyzed. From the peak locations of these tracers, ground water recharge rate was determined from the profile distribution of these tracers. Uncertainty associated with these recharge rate estimated was also analyzed.

H21C-04 0830h POSTER

Temporal And Spatial Aspects Of River-Groundwater Exchange In The Regulated Rhone River (Switzerland) Using Chemical And Physical Tracers

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Over the last two centuries most river systems in Central Europe have been regulated to improve flood protection. Large hydropower schemes were developed in the Swiss-Alps, which strongly modified the hydrological cycle. As a consequence of increasing number of flood events, the upgrading and renewal of flood protection dikes in the lowlands is often combined with river restoration projects today. Because this often involves removing or dislocating dikes, the planning and design of such projects under consideration of both flood protection and hydropower schemes should be based on a detailed knowledge of river-groundwater interactions. We test and apply a combination of different chemical and physical tracer methods to qualitatively and quantitatively approach these interactions in the channalised Rhone river reach upstreams of lake Geneva (Switzerland). With these tools we address a series of questions like: 1)Can the seasonality of delta-18O in precipitation be used to distinguish between the hydrological cycles above and below the catchment basin of the hydropower plants? 2)Can we quantify the water exchange between the river and the groundwater in the alluvial aquifer? 18O and sulphate as a tracer: Due to the geological situation -high altitude differences and the presence of gypsum in the Penninic nappes on the south side of the valley, 18O and sulphate concentrations prove to be the most effective parameters to study water exchange. Monitoring stable isotopes in precipitation of different altitudes shows more depleted signatures in winter than in summer. However, this pattern is reversed in the receiving river of the valley ground. The delta-18O winter values in the river (-13.3 to -14.2 permil) are more positive than in summer (-15.2 to -14.4 permil), with variations in delta-18O up to 0.8 permil. This means that the seasonality in the river water (more negative values in summer than in winter) is reversed in comparison to the seasonality in precipitation. Sulphate river concentrations in winter are significantly higher than in summer and scatter largely because of strong influence of the daily runoff fluctuations caused by hydropower production. Temperature and hydraulic pressure as a tracer: The flood protection dike on both sides of the Rhone forms a clear interface between the groundwater and the river itself. In order to evaluate the effects of hydropeaking across the dam, water level and temperature were determined in groundwater wells in different distances from the river. The water level of the Rhone reflects the cycles of hydropeaking. From Monday through Friday, the water level fluctuates daily by approximately one meter. The same behaviour is observed in wells on either side of the dam but the amplitude is attenuated. When the turbines are switched off on Friday evening, the groundwater level stabilises at a lower level, as does the water level of the Rhone. When monitoring the temperature variations in the groundwater, some wells within the dike structure show a regular pattern corresponding to the hydropeaks in the river. Daily temperature fluctuations are 0.1-0.2 degree Celsius. Weekends show a temperature rise by as much as 0.4 degree Celsius. Cross correlating the long-term databases of the pressure and temperature signals provides information about clogging of the river border and allows partial quantification of water exchange between the river and the groundwater.